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IMPORTANT DETAILS OF SPRAYING.

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INTRODUCTORY.—Within the last ten years there have been many bulletins and other publications on the subject of spraying. Nearly all of these treat the subject from the standpoint of the kinds of mixtures to be used; some treat of the desirability of spraying at all, but very few, if any, treat of the little technical details of the operation which constitute the fundamental principles and which go so far to make successful results possible. The Illinois Station has already issued three publications on the subject (Circulars 8 and 37 and Bulletin 54); but they, too, may be included in the above classes. While traveling over the fruit districts of Illinois during the past season the writer saw many well-meant but unsuccessful spraying efforts. The Illinois growers are enthusiastic sprayers when once convinced of the practicability and

profit of the operation, and most of them are very well posted on the parts of the subject so thoroughly treated in the many publications referred to. But upon the essential details a lack of knowledge is so manifest that it has been thought wise to explain thoroughly the underlying principles, and thus give the growers of the state a chance to think and act for themselves in putting these fundamentals into successful practice.

Spraying is the most expensive of our orchard operations. It is at the same time the one most easily slighted, for it is the most exacting throughout the entire process. Good apparatus, pure materials, and, above all, patient and intelligent attention to every detail in the mixing and application are prime requisites for success. No part of the process can be slighted with impunity. It is not enough to go out whenever other work is not pressing and squirt around in a hit or miss fashion, expecting luck to do the rest. The time at which an insect pest or a fungous disease can be successfully combated or prevented is in most cases extremely short. Often a difference of a day or two is sufficient to change success into failure. Thus, in the case of the codling moth, as is well known, it is impossible to reach the worm after it has once got well into the fruit. So with the scab or the bitter rot: after the germinating tube of the fungus has once penetrated it, cannot be reached, and the mycelium will continue to grow and develop despite the presence, afterwards, of a fungicide. The importance, then, of doing the work just at the proper time cannot be too strongly emphasized. When the proper time comes everything else must "take a back seat." Get on the land somehow. If it is wet and muddy, devise some means of overcoming this: use a sled or put on extra wide tires—anything to get the work done at the proper time. And you who have large areas to cover, be sure you have apparatus enough to get over the whole place within the proper time. Steam and power sprayers are now coming into use both in New York and California, and there can be no doubt that after we know more about them we shall be able to adapt them to our conditions here.

CLASSES OF MIXTURES.—Spray mixtures may be divided into two general classes, depending upon the class of enemies they are intended to combat, viz.:

1. Insecticides.
2. Fungicides.

Of the first class, there are two divisions or sub-classes, viz.:

(a) Poisonous mixtures or solutions *to be eaten* by the insect along with the part of the plant or tree attacked.

These mixtures are effective only against the chewing insects; e. g., codling moth, canker worm, tent-caterpillar, leaf skeletonizer, and the like, and kill only after being eaten. In this respect they differ essentially from

(b) Mixtures or solutions with more or less caustic or penetrating properties, which kill *wholly by contact* with the insect. This class of mixtures can be used effectively against both classes of insects, but is employed almost wholly against insects with sucking mouth-parts, such as the scale-insects, the plant-lice, mealy bugs, and the like. These insects obtain their sustenance by *sucking the juices* of the part of the tree which they attack, and cannot therefore be reached through their food supply.

The second general class of mixtures, the fungicides, are also of two kinds, depending upon the character of the fungous disease which they are intended to check. There are two kinds of fungi attacking living plants:

(a) Those which grow on the surface of the parts attacked and which therefore have their mycelium exposed. The powdery mildews of the grape, the gooseberry, and the rose are the most common diseases of this class.

(b) Those which grow wholly *within* the plant tissues, and which therefore have their vital parts, the mycelium, wholly protected from man's attack. Most of the fungous diseases of plants belong to this class. The bitter and brown rots, the black rot, downy mildews, cankers, and hosts of other troublesome pests, all come under this head.

Naturally then, the remedies used against these classes of fungi differ materially in their action. The first mentioned are easily reached and *killed* by the fungicide coming in contact with the exposed mycelium. The remedies against the last mentioned class cannot reach the vital mycelium, and therefore can be *preventive* only in their action. The fungus must be checked before it penetrates. This cannot be too strongly emphasized; for upon this fact depends the successful use of the fungicides against this class of diseases. In order to bring out more clearly how this is, it will perhaps be well to get some idea of just what a fungus is and how it grows.

WHAT IS A FUNGUS?—A fungus is a plant, differing essentially from the higher plants common to us in the absence of chlorophyl, or green coloring matter. It has its roots and stems, the mycelium,

and its means of reproduction and spread, the spores, analogous to the seeds of higher plants. The spores are perhaps the most important parts of the fungus, from the point of view of the fruit-grower, for it is by means of these that the fungus is reproduced and spread from leaf to leaf, from fruit to fruit, from tree to tree. Any agency which may disseminate the spores may be the means of spreading the disease. Winds, rain, birds. and insects are all known to act in this capacity.

HOW A FUNGUS GROWS.—Let us see, then, what happens when one of these spores falls, or is placed upon the surface of a leaf or fruit. As soon as the conditions of heat and moisture are favorable it will germinate, just as a seed does, and send out a tube, which, if it belong to the surface-growing class, will branch and continue growing on the outside, while if it be of the penetrating class, it will penetrate the skin and there continue its growth.

HOW THE FUNGICIDE ACTS.—It is important to remember that the fungicide is non-effective against the spore itself; it is also, as has been pointed out, ineffective after the tube has penetrated. The germinating tube itself, therefore, is the only part of the fungus which is destroyed by the spray. Plate I. shows the appearance of the spores before and during germination, showing the tube against which the fungicide is effective. It will be seen, then, that the remedy is entirely preventive; that the spore must germinate before the fungus can be destroyed and therefore the necessity of having the leaves or fruit *entirely covered* by the spray is strongly emphasized. If there are any breaks in the coating of the mixture, the exposed spot is liable to attack, and if attacked becomes a source of infection, the birthplace of a new crop of spores, ready to go out upon their mission of destruction. It will also be readily seen that good spraying is really cumulative in its effect, for naturally if we succeed in destroying all the way from 80 to 100 per cent. of the germinating spores of a few seasons, the number will become so reduced that the attacks can be all the more easily and readily controlled.

(a) Before germination. (b) During germination.

PLATE I.

BITTER ROT SPORES AS SEEN UNDER THE MICROSCOPE.

PHYSICAL PROPERTIES OF MIXTURES.—Leaving aside their fungicidal or insecticidal properties and considering them solely from the point of view of their physical nature, we find that the classes of spraying compounds now in use may be grouped under three heads:

1. Those involving the suspension of insoluble substances in water, e. g., Paris green, Bordeaux mixture.
2. Simple solutions, e. g., ammoniacal copper carbonate, sulphid of potash, copper sulphate.
3. Emulsions or mechanical mixtures of oily or waxy substances with water. The most important of these is the kerosene emulsion, or, as at present used, the kerosene water mixture without the use of an emulsifying agent.

It is important to keep the differences between these classes of spray mixtures ever in view; for upon them depend not only the mode and manner of application, but also their action upon the insect or fungous pests which they are intended to combat. It will be well, then, to consider each group in detail, and determine, as far as possible, the important points bearing upon their behavior and handling.

MIXTURES CONSISTING OF MATERIALS SUSPENDED IN WATER.—In the first class insoluble compounds are dealt with; and it will be noticed that they are to be suspended in water and applied while in suspension. It is important, then, that the mixture be thorough, in order that the material may be equally disseminated throughout the liquid. Suspension is brought about and kept up by means of agitation. It is highly important, therefore, that the agitation of the mixture be most thorough, for, unless it is, two evils will result—the first portion will be too weak to do effective work, and the last will be so strong that the trees will be injured. The writer has seen the effects of this kind of spraying in this state. This may seem an old and well-known fact, but it is of far more importance than a great many growers suppose.

SOMETHING ABOUT AGITATORS.—The agitators now in use are far from perfect or satisfactory, especially upon long, flat tanks; and unless they are continually watched, unequal dissemination is likely to result. It is not to be forgotton that the liquid must be kept in motion *throughout* the tank. It is not alone necessary that a current be created near or around the opening into the pump. For this reason the whirling paddle is perhaps the best, especially if constructed with tilted blades, something like a screw propeller. (See Fig. 1.) It is a common practice nowadays to attach a paddle

to the pump handle, so that the agitation may be maintained with every stroke of the operator. At first sight this seems to be a good plan, but it is, really, a mistake. If the paddle is a satisfactory one, the labor to keep it going will be far too great when added to that of pumping, and, in consequence, the one will interfere with the other. Besides, a violent or quick motion is necessary for thorough agitation, while for pumping, a regular, steady stroke is the best. Therefore it is best not to attempt to couple the two motions.

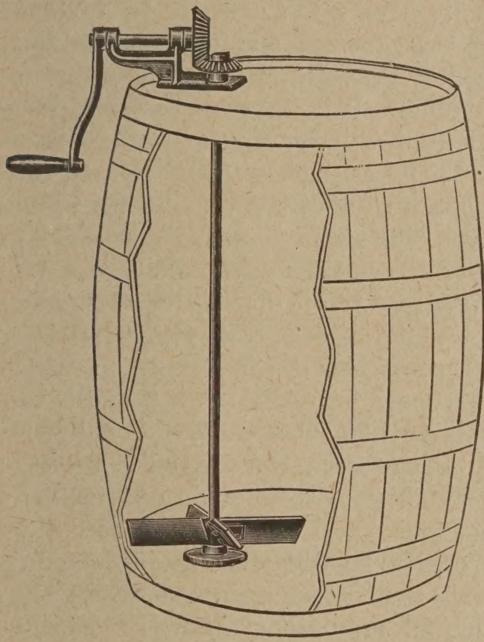


Fig. 1.

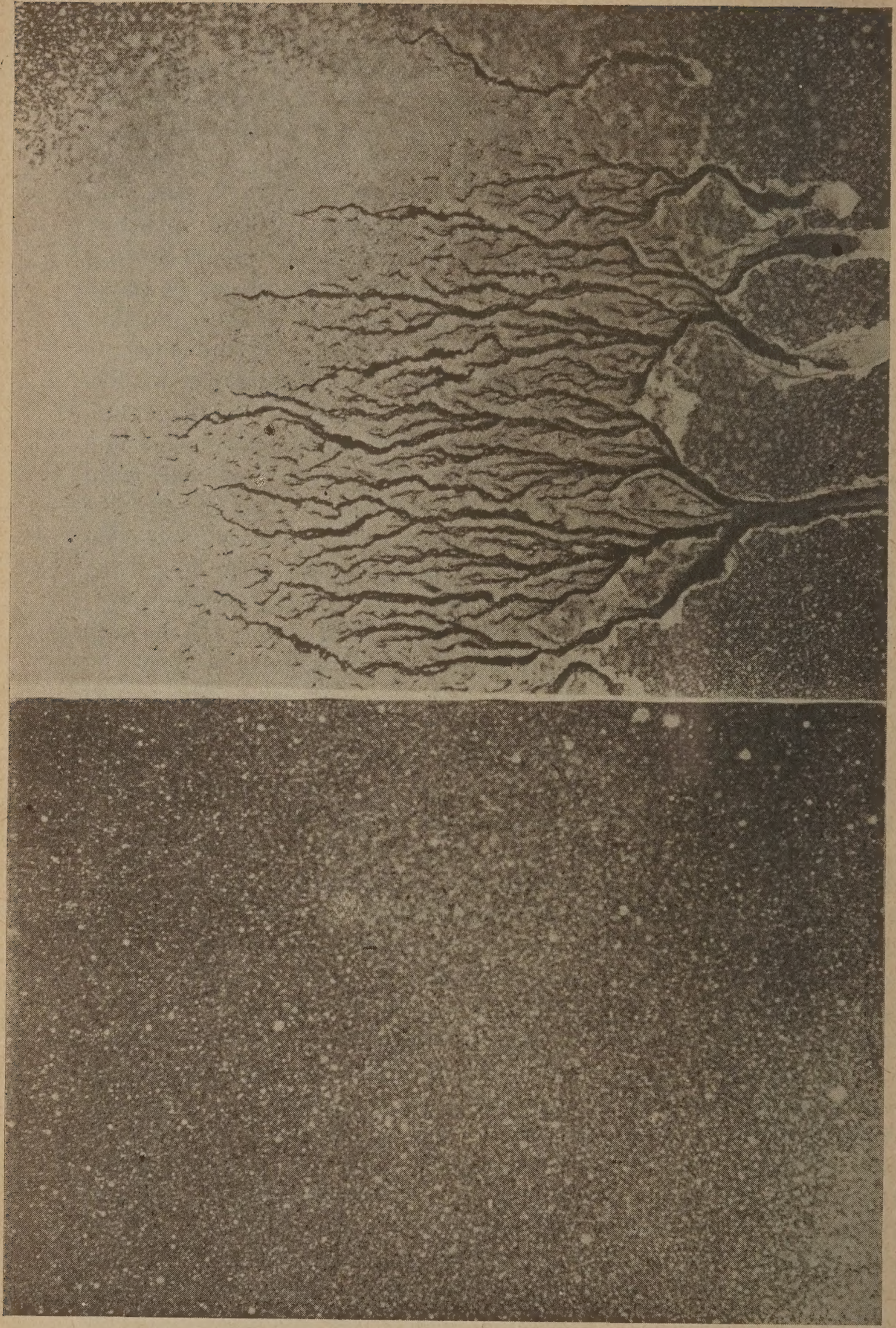
Paris green, when used alone, is, perhaps, the only material which requires continual agitation; and that, in the opinion of the writer, is a serious objection to its use, now that lighter-grained poisons have been found which settle much more slowly and consequently do not need continuous agitation. If we omit Paris green from consideration, the liquids now in general use can be sufficiently stirred at short intervals — best while the rig is moving from one tree to another. A separate agitating device is therefore preferable. The operator can do more with the few vigorous turns he is then able to give the agitator than is possible when the motion is dependent upon the pump handle. On large, flat tanks it is practically impossible to keep up a sufficient pressure and thorough agitation with the same stroke by hand. Two or three paddles are necessary, depending, of course, upon the length of the tank. These can be connected to a lever on top, a few vigorous strokes of which, at intervals, will suffice to keep up a very thorough dissemination throughout the tank. The writer saw a very effective and ingenious home-made device last spring used by a fruit-grower near Geneva, New York. This man had rigged up a pulley attachment to one of the wheels of his spray wagon. Over this pulley a belt was run, which communicated mo-

tion to an arrangement on top of the tank for moving the agitating paddles. In this way the agitation was very easily and effectively maintained. Such an arrangement could very easily be put on at slight expense by any of the growers of this state. Of course, where steam or other power is employed both agitation and pumping are easily maintained by the engine or motive power.

PROPER PLACING OF PUMPS ON BARRELS.—Just a word about barrels. It is now almost the universal custom to place the pump on the end or head of the barrel. For the purpose of the class of spray mixtures now before us, it is very much better to have the pump on the side. When the barrel is laid and used on its side, as it must be in that case, most of the settling material will go towards the depression at the middle. It is therefore easier to keep it in motion, for the sloping bottom will aid in the work. As at present placed, the flat bottom gives a larger settling area to control, and will require more force to dislodge the sediment from around the edge of the bottom, while the comparatively straight sides retard rather than aid the necessary motion. If any one will place a small quantity of Paris green into a flat-bottomed tumbler containing water and then try to dislodge the grains sticking around the bottom, he will get some idea of the conditions which exist inside the upright flat-bottomed barrel. If you perform this little experiment, note at the same time how exceedingly difficult it is to dislodge the material by imitating the dipping motion of the paddles now in general use. Note also how very much more effective is a whirling motion.

HOW TO SPRAY PROPERLY.—Having the mixtures properly prepared and thoroughly agitated cannot alone insure success. Unless the spray is properly applied, all preliminary effort is lost. To spray properly is more difficult than is usually supposed, especially where materials in suspension are used. It will not do to go out with a determination "to do a thorough job and give them an everlasting soaking" until everything is dripping. If this is done, there will be less material on the trees in the end than if less were applied in a proper manner. This to some may seem paradoxical. Nevertheless, it is a fact, and an attempt will be made to show just how it takes place. In order to do this it will be necessary to consider the globules of water as they come from the nozzle, carrying with them suspended particles of Paris green or Bordeaux mixture, or both, as the case may be. The settling which takes place in the spray tank goes on within the globules of water after they become fixed to the fruit and leaves. Hence the larger the globule, the more settling will take place, and conesquently the more material

will be deposited at one place. The only way this can be avoided is to have the globules very small and fine as they leave the nozzle, and to keep them intact as separate, fine globules after they become attached to the fruit or leaf. Hence, the importance of the injunction: "*Use only a fine nozzle; use force enough to keep the liquid issuing as a fine mist; and spray only until the foliage and fruit are completely bedewed.*" It requires considerable skill to do this properly and cover the surface fully. If it cannot be done with one spraying, it would pay better to go over the trees twice, allowing the first application to dry before giving the second, than to try to accomplish it all at one time, and thus run the risk of going further than the simple bedewing of the fruit or leaves. If the spray is continued too long, the fine globules will "run together" to form one or several large ones, which, instead of remaining fixed and drying just where they strike, will run down to the lowest place and drip. Of course, the suspended material settles to the lowest point of the globule, which is, in that case, spread over a considerable surface of the fruit. Some of the upper portions are thus left completely bare. At the lower edge the material will drip off with the water, or often accumulate in sufficient quantity to cause injury. Plate II. shows reproduced photographs of glass plates sprayed with dilute milk of lime, having the same proportion of suspended material as Bordeaux mixture. (a) was sprayed just to the proper point and (b) beyond that point, or until the globules ran together and trickled down in streams. It will be noticed that (a) is quite uniformly covered, as is also the upper portion of (b), but note what has happened where the running together took place: The glass has been left perfectly bare in streaks, while at the ends of these little rivulets, the lime has accummulated, and where they dripped off the glass, the material in suspension went with them. Now, this is just exactly what takes place on the fruit and leaves of our trees. Plates III. and IV are examples of fruit and leaves properly and improperly treated. The plates were all made from photographs, and show the imprints of the fine, separate globules, leaving the surfaces quite uniformly covered on the properly sprayed specimens, while the oversprayed shows how the running together has left a large portion exposed to attack. Where the bitter rot or the scab is very abundant, an apple or a leaf in the condition of those shown in Plates III. (b) and IV. is little better off than if it had not been touched at all. Unfortunately, plates which show the injury from the accumulation of Bordeaux or Paris green at the edges were unobtainable. Plate IV. shows a similar injury brought about by the accumulation of a soluble spray—the ammoniacal copper



(a) Sprayed just to the proper point. (b) Sprayed too long.

PLATE II.

carbonate—by running down and evaporating at the edge; and it will serve very well to illustrate the injurious effect of such accumulation. (It may be stated here that these leaves were injured by a solution containing nearly ten times the usual quantity of copper carbonate, while the leaves of another tree properly sprayed with the same solution were not injured at all. The importance of precaution in this respect cannot, therefore, be too strongly emphasized.)

MIXTURES CONSISTING OF SIMPLE SOLUTIONS.—The second class of spray mixtures, those which consist of diluted solutions, must be handled in different ways, depending upon whether the spray is to be used as a fungicide or an insecticide. If the former, then all the precautions mentioned before regarding the maintenance of the spray as a fine mist upon the surfaces, are necessary and important; otherwise the material will accumulate at the lowest point by evaporation, and not only leave the upper portions unprotected, but may be seriously injurious, as in the case of the illustrations mentioned above and exhibited in Plate IV. If, on the other hand, the solution is used as an insecticide, intended to kill by contact, then a coarser nozzle and a direct stream is not only allowable but even desirable. In most cases the spray has done its work, if at all, just as soon as it has struck. It is not important then, that it remain on the trees; rather the reverse is often desirable. Of course injury from the accumulation by evaporation at the lower edges is liable to occur if too strong a solution is used, or if it is allowed to run down the tree trunks and saturate the ground around the root crowns.

EMULSIONS.—Mixtures of the third class are practically all used as insecticides against sucking insects,—scales, aphidæ, and the like, which, as mentioned above, can only be destroyed by contact with the mixture. Again, a large proportion of the mixtures of this class are intended for winter use, when the trees are dormant, and are, therefore, not subject to the same rules as those used when the foliage is present. A somewhat coarser nozzle is essential, for in this case a direct stream, so that the mixture strikes with considerable force, increases the effectiveness of the spray. A great many of the insects of this class are protected either by a thick, waxy exudation or by a hairy or woolly covering, and, in order to penetrate these, it is necessary for the liquid to strike with considerable force. The writer has sprayed the plum aphis with kerosene-water mixture, using an ordinary fine Vermorel nozzle, without effect; while the same mixture put on through a coarser nozzle, so that a direct stream was possible, did the work effectively. In this case, every part of the tree must be thoroughly wet, and it matters

(a) Sprayed to the proper point.

(b) Oversprayed.

PLATE III.

APPLES PROPERLY AND IMPROPERLY SPRAYED.

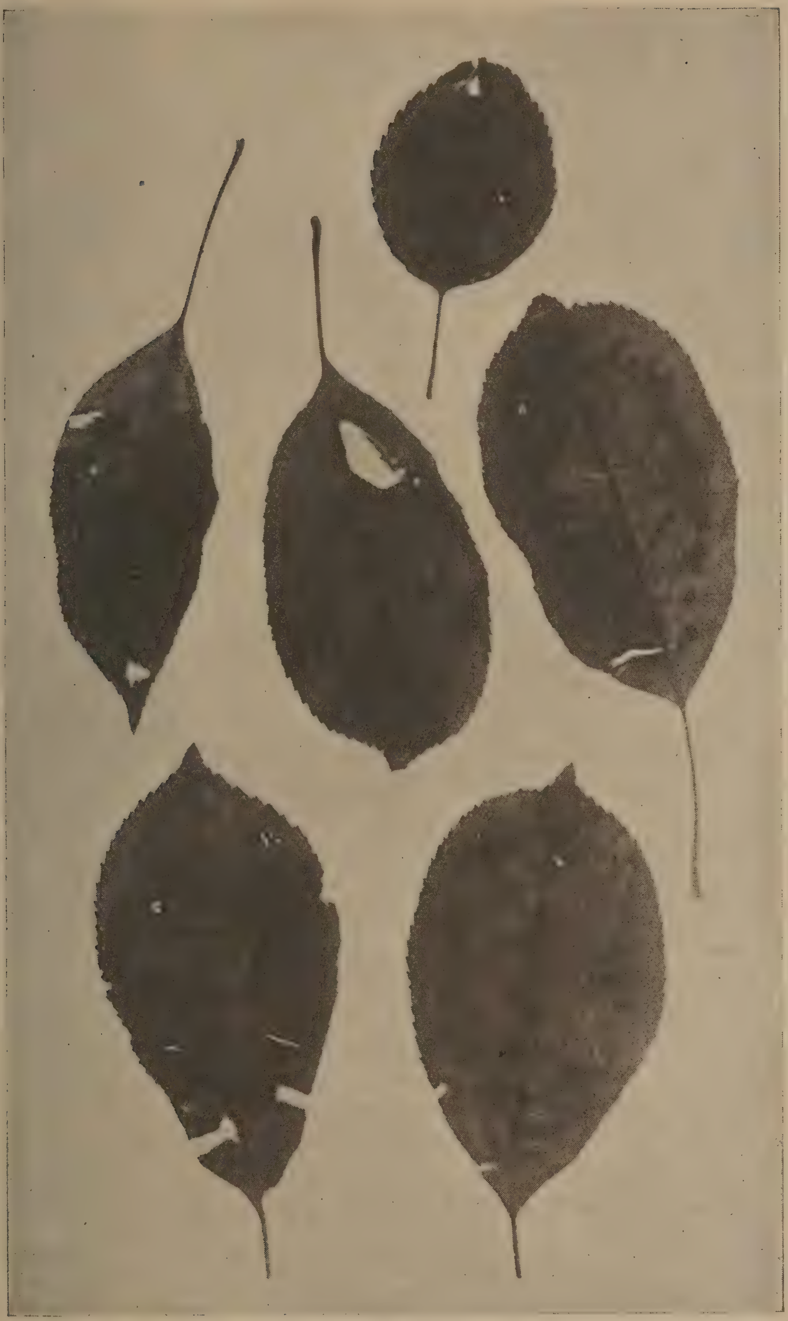


PLATE IV.

APPLE LEAVES SHOWING THE RESULTS OF THE ACCUMULATION OF THE SPRAYING-MATERIAL AT THE EDGES BY RUNNING-DOWN AND EVAPORATING. THE DARK EDGES AND SPOTS REPRESENT DEAD PATCHES ON THE LEAVES.

little if there is some dripping. Care must be exercised, however, to avoid saturation of the ground around the root-crown by the liquid running down the tree trunks.

Paris Green, Bordeaux Mixture, and Ammoniacal Copper Carbonate Solution.

So far nothing has been said regarding two of the principle factors in successful spraying, viz., the purity of materials and the proper methods of mixing. There are, perhaps, scores of materials available for the destruction of insects and fungi, but for present purposes we need to treat of only the three in general use in Illinois orchards—Paris green, Bordeaux mixture, and ammoniacal copper carbonate solution. Probably nine-tenths of the spraying done in this state at the present time is done with these three.

Paris Green.—This substance, the aceto-arsenite of copper, was formerly manufactured solely for use as a pigment in painting. As such its prime requisite was a bright green color, together with some insolubility in water. Its composition was of little importance. It has, however, now come into such extensive use as an insecticide—a use which makes its composition a prime requisite—that a demand has been created for a material specially prepared for this purpose. In the last few years this demand has been partly, at least, satisfied; and there are manufacturers who are now preparing Paris green solely for use as an insecticide. The increased demand for the poison led to so-called improvements in its method of manufacture, resulting in a shortening of the time and a consequent increased product, but, of necessity, attended by less care in its preparation, until in late years the ordinary commercial Paris green, at best a variable compound, has become so exceedingly variable in its composition that its use has led to not only unsatisfactory, but even harmful results. The experience in this state is no exception, especially during the past season. Much dissatisfaction with the results of spraying operations has been expressed on all sides. It is, therefore, highly important to point out some of the pre-requisites of a satisfactory article.

In the first place Paris green should have its full complement of arsenic, for upon that depends its effectiveness as a poison. Thus, for example, if a fruit-grower use a green containing from one-fourth to one-half the quantity of poisonous principle presumed to exist therein, his spraying will fail to kill a large percentage of the worms unless the dose is correspondingly increased. Paris green should contain from 50% to 56% arsenious oxid, which, in the second place, should be *practically all in combination with copper*. Free

arsenious oxid is soluble in water after a time, and when it is present in Paris green to any great extent, destroys one of the latter's most valuable qualities as an insecticide, its insolubility in water. It is this latter quality which makes its use possible without injury to the foliage. Arsenious oxid in solution is at times extremely injurious. This seems especially true in drier localities or during dry spells having hot days followed by heavy dews or fogs at night. The dew dissolves the arsenic, which is then absorbed in sufficient quantities by the leaves to cause serious injury. This is as far as our knowledge goes at present. More investigation and experimental work are needed on this subject; for at times it has been possible to apply pure solutions of arsenious oxid without injury. But until we know definitely what conditions are favorable or unfavorable to the absorption of the arsenic, it is safe to use only the insoluble material. It is highly essential, then, that the grower know definitely just what grade of green he has to deal with. There are a few simple home tests which will show readily whether a sample is badly adulterated or not, but the determination of the exact composition can be made only with special appliances, or by some one with a knowledge of chemical analysis. The department of horticulture will examine and report upon samples of green submitted by growers, so far as its means will permit. There is need for legislation in this matter, however; the department will second any efforts on the part of growers in this direction, and will be pleased to advise regarding the proper provisions of a Paris green law.

Color Tests.—Perhaps the simplest test to determine whether a green has been extensively adulterated is the color test. Pure Paris green has a bright green color, a shade or two lighter than emerald. Any samples which have a dull or a pale, washed-out appearance should at once be discarded without further question. By placing a small quantity in, say, a homeopathic vial, and tapping the latter gently on the bottom or side, adulterants can be made to separate from the green, and can then be seen as white streaks or patches against the glass sides of the vial. The pure green remains bright green against the glass. In connection with the color test, Professor Woodworth of the California Station has devised the following simple test[1], which can be made by any one and which will show immediately if the sample is worthy of any further consideration: Place upon a clean glass plate a small quantity of green, what one can easily pick up on the point of a pen knife; tilt the plate at a slight angle and gently tap the edge, just enough to

1 Bull. 126, Cal. Exp. Sta. "Paris Green for the Codling Moth," p. 12.

cause the green to flow down leaving a streak across the plate. If the green is of good quality, the streak will be a bright, light emerald green; if adulterated, a whitish or a sickly dull green. Any samples which exhibit the latter are either adulterated or of low grade and as such are not worthy of further consideration.

Ammonia Test.—Another very simple way to show the presence of adulterants is the ammonia test. Pure Paris green is wholly soluble in ammonia, while some of its common adulterants are not. Therefore, if after dissolving a small quantity in ammonia, any residue remains undissolved, the sample has been adulterated and should be discarded. Unfortunately, this test does not show the presence of any free or uncombined arsenious oxid, which, although it has not been considered strictly an adulterant (on the ground of its poisoning qualities), is nevertheless objectionable on account of its injurious action on the foliage. A large percentage of uncombined arsenious oxid may result from careless manipulation in manufacture. It is also often put in during manufacture to bring up a low grade green to the full strength of arsenic. In either case its presence in the uncombined state is objectionable and should be known.

Microscopic Test.—One of the quickest and surest means of determining the presence of any adulterant or objectionable ingredient is the compound microscope. Placed under an objective of medium power, say one-quarter inch, Paris green is seen to consist wholly of clean, green spheres, and in a pure sample this is all that can be seen. Plate V. is the reproduction of a photo-micrograph of a high-grade sample. A low-grade green will have something of the appearance shown in Plate VI. In addition to the clean, green balls a number of crystals are seen, which are almost wholly those of free arsenious oxid put in to make up the strength of a low-grade article. When the arsenic is added in the process of manufacture or results from careless manipulation, it is more difficult to detect it. In that case, it is usually found sticking to the green balls themselves, giving them an irregular outline and causing them, on the whole, to aggregate into masses instead of remaining in separate, clean particles. The plate shows the appearance of these aggregates with their clinging crystals, but it is often very difficult to see them.

The appearance of a wilfully adulterated sample, however, cannot be mistaken. In Plate VII. we have an exhibit of the marked characteristics of a sample which cannot be designated by any other term than "bogus," and so it has been labeled. This green was labeled "Strictly Pure Paris Green." Note the long, needle-like crystals, which are, in all probability, those of gypsum, cal-

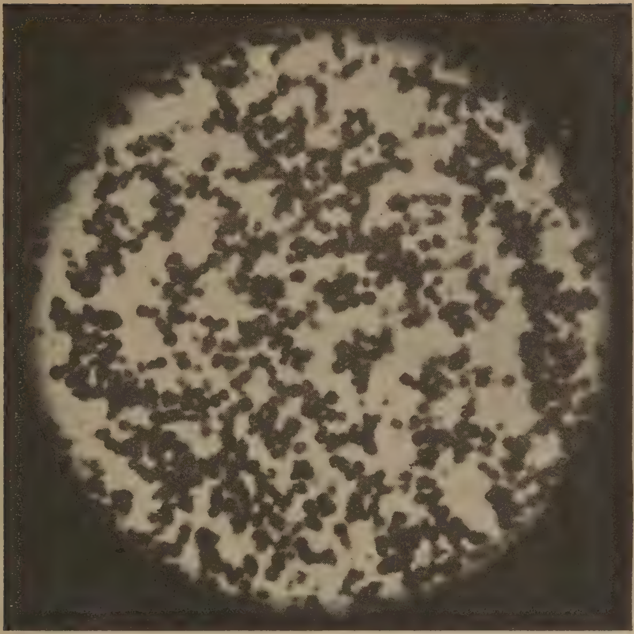


PLATE V.
HIGH-GRADE PARIS GREEN AS SEEN UNDER THE MICROSCOPE

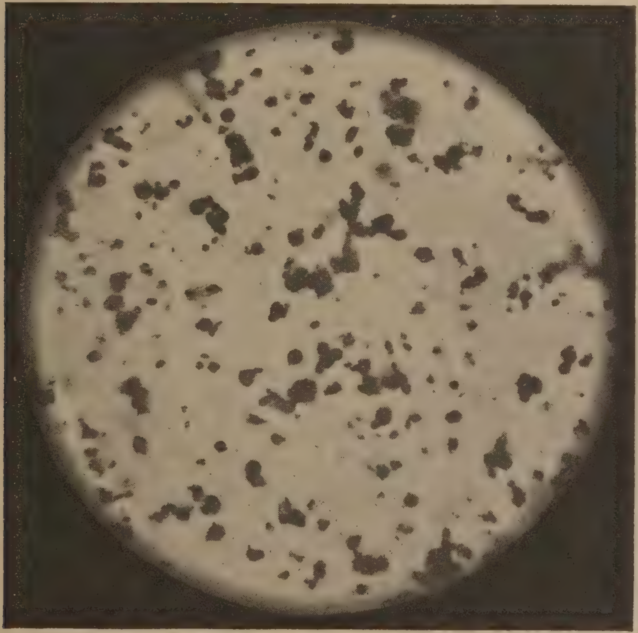


PLATE VI.
LOW-GRADE PARIS GREEN AS SEEN UNDER THE MICROSCOPE.

cium sulphate, and there can be no legitimate excuse whatever for their presence. These, together with the preponderance of the

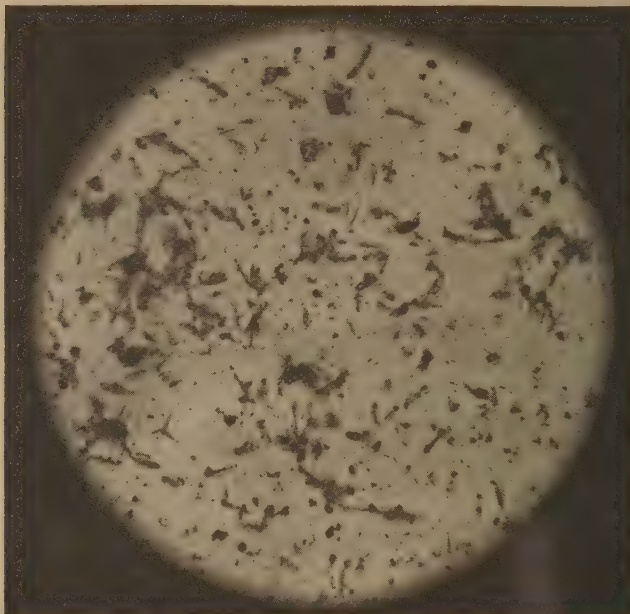


PLATE VII.
BOGUS PARIS GREEN AS SEEN UNDER THE MICROSCOPE.

smaller crystals and the absence of the clean, green balls, make the name "Paris Green" a fraudulent misnomer for this compound.

ALLOWABLE LIMIT OF UNCOMBINED ARSENIOUS OXID.—Of course, it is practically impossible to manufacture an absolutely pure commercial Paris green without any uncombined arsenious oxid; but it has been demonstrated that it *is* possible to keep down the free arsenic below the danger point. In California this has been found to be about 4%, and that percentage has been placed as the allowable limit in their Paris green law passed last year. In many of the state Paris green laws (e. g., that of New York) no such limitation is made. It is well to note here that since the passage of the California law above referred to, it has been found that a number of the manufacturers are now producing two grades of green, one for the California trade, meeting the requirements of their law, and the other for sale in states where no restrictions are placed upon the uncombined arsenious-oxid content. This in itself is significant, and shows that it *is* possible to manufacture a proper article.

EFFECT OF THE ADDITION OF LIME.—It has long been known that the addition of lime lessens the injurious action of the free arsenious oxid by rendering it insoluble. This is true up to a certain point. If the percentage of free arsenious oxid is very high the lime will do no good, and may even be harmful; for it has been shown that lime acts upon white arsenic, when it is in suspension in water, in some way that greatly increases its injurious effect upon the foliage.

REQUIREMENTS OF A GOOD PARIS GREEN.—We might, therefore, sum up the points of a good Paris green as follows:

1. It should be a wholly dry and impalpable powder. Grittiness and caking are evidences of adulteration.

2. It should have a bright, light emerald green color, which should not whiten or become dull in the streak left in passing a sample across a clean glass plate.

3. It should be entirely soluble in ammonia. Any residue is an adulterant.

4. Under the microscope it should be seen to contain only a trace of foreign matter, and should consist of *clean*, green spheres, wholly separate from one another. Aggregation into masses is evidence of careless manufacture.

These are all the points which can be readily determined. In addition, to the above should be added the most important point, but one which can be determined only by a chemical analysis, viz:

5. Paris green should contain not less than 50% of arsenious oxid, of which not more than 4% should be in the free state, or uncombined with copper.

OBJECTIONS TO THE USE OF PARIS GREEN.—Perhaps the most serious objection to the use of Paris green is the rapidity with which it settles in the spray tank. This renders the problem of agitation doubly important and difficult; for without the most careful attention and more satisfactory agitating devices than those now in use, it is practically impossible to secure a uniform distribution of the poison. There are differences in this respect in Paris green of different manufacture and even in different lots put up by the same manufacturer. A coarse, heavy-grained article will naturally settle more quickly, other things being equal.

It should be remarked here that when Paris green is used with Bordeaux mixture, the latter helps to keep the poison in suspension. A few of the heavier particles of the green go straight to the bottom, as they all do when used alone; but the majority remain mixed with the Bordeaux precipitate and settle slowly with it. If, therefore, Paris green is applied with properly prepared

Bordeaux mixture, much of the serious objection to its use, on the score of its rapid settling, will be overcome.

SUBSTITUTES FOR PARIS GREEN.—There have been so many objectionable features in the use of Paris green that different arsenical compounds have been suggested as substitutes. A few of these have been extensively tried and are very promising, especially where the mixtures have been home-made. Much has been said and written about the disadvantages, great labor and danger of preparing home-made compounds, and the advantage of Paris green in being ready to use just as it comes from the store. But it has now come to be generally recommended to add lime when preparing the green for use. This destroys the ready-to-use advantage of Paris green. Why not, then, go a step further and prepare a mixture of known composition and thus do away with all the uncertainties of commercially prepared articles? Several of the substitutes, notably the arsenate of lead and arsenite of lime, possess the additional advantage of being much smaller and lighter-grained, and consequently remain much longer in suspension. In addition, these can be used much stronger without injury.

The home-made substitutes are growing rapidly in favor, and will, perhaps, largely supplant Paris green in the near future. The writer is at present investigating the properties of the different arsenical substitutes. While, apparently, very striking results have already been obtained, some points yet remain to be investigated, and the data will have to be reserved for a later publication.

COMMERCIAL SUBSTITUTES FOR PARIS GREEN.—Of the commercially prepared substitutes, usually sold under the title of "arsenoids," it need only be remarked that these are without exception, perhaps, open to the objectionable uncertainties of all articles manufactured on a large scale; at least until manufacturers are willing to make their preparations conform to the rational requirements of spraying purposes.

BORDEAUX MIXTURE.[1]—This fungicide is now the most generally used and is perhaps the most important mixture employed in spraying operations. Discovered accidentally, about twenty years ago, its development has been remarkable, until at present it is noted as the best fungicide known. Fortunately, in this case there is little to fear from impure materials. Commercial copper sulphate is so staple an article that so far not a single complaint has been brought against it on the score of impurity. Lime is more variable. In some localities it is exceedingly unsatisfactory,

1. Four pounds copper sulphate, four pounds lime and fifty gallons water have now become the standard formula in Illinois.

wholly on account of the poor class of rock from which it is manufactured. Of course, where this is the case and poor lime must be used, it goes without saying that a larger quantity is necessary. Moreover, the quantity should never be gauged by measure alone. The ferrocyanide (yellow prussiate of potash) test is the safest way to determine the proper lime-content. For this purpose use a solution made up of about 1 oz. of ferrocyanide of potash to 5 or 6 oz. of water. When the Bordeaux has sufficient lime the addition of a few drops of the solution will produce no discoloration ; but when insufficient, a dark brown discoloration results. Many simply pour a few drops of the solution into the mixture while in the tank or barrel. This is really not safe. The slight discoloration, resulting from the presence of a small quantity of free copper sulphate, cannot be seen in the spray tank. It is eminently desirable to have *all* the copper in combination, and to be certain of this it is advisable to have a slight excess of lime, which does no harm. It is best, therefore, to dip out a small quantity in a saucer or other shallow white china dish for the test. The slightest discoloration will then be visible against the white ground of the dish. Before performing this test it is necessary to have the liquid thoroughly stirred. It is best to make two tests, giving a vigorous agitation between them. After such treatment the writer has often found the second test to result differently from the first. When they are both alike it is quite certain that the results are correct. As the ferrocyanide is a virulent poison it is essential to keep the solution distinctly labeled and out of reach of children or careless persons. When large quantities of stock solution of copper sulphate and lime milk are made up, one test with the ferrocyanide will be sufficient for the whole quantity ; i. e., the one test will indicate the proper proportions for the stock solutions on hand. Another excellent method is to standardize the lime milk by making first a small quantity of test mixture. This can be done as follows: Make up the stock solution of copper sulphate as usual, one pound per gallon of water. Slake the lime, making of it a thin paste. Now take one pint of the copper sulphate stock solution, dilute to about a gallon, and add to that small measured quantities of the lime, testing after each addition, until the sulphate has all been "neutralized." From the quantity of lime thus used the necessary dilution can be calculated to make the lime milk any desired strength. The proportion of water necessary to make the proper dilution will be equal to the difference between the required strength and the quantity of lime milk used to neutralize the sulphate, expressed in fractions of that strength. Thus, if one-half

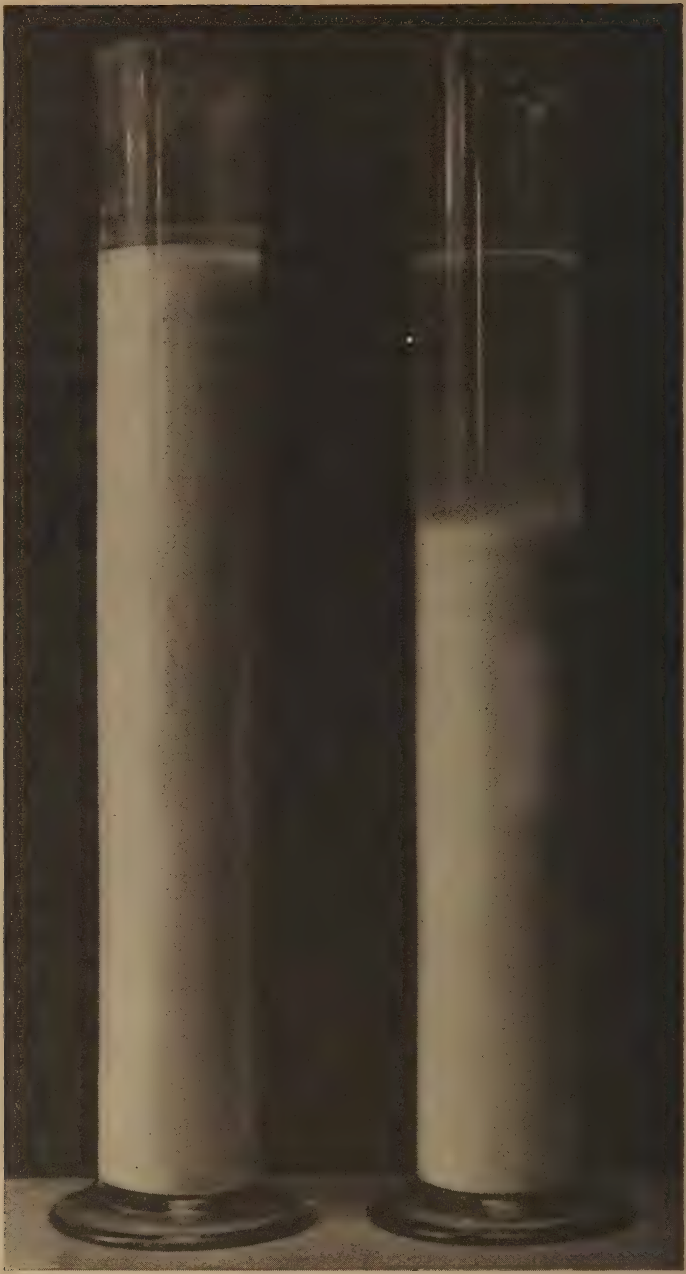


PLATE VIII.

BORDEAUX MIXTURE PROPERLY AND IMPROPERLY PREPARED, AFTER SETTLING TWENTY MINUTES.

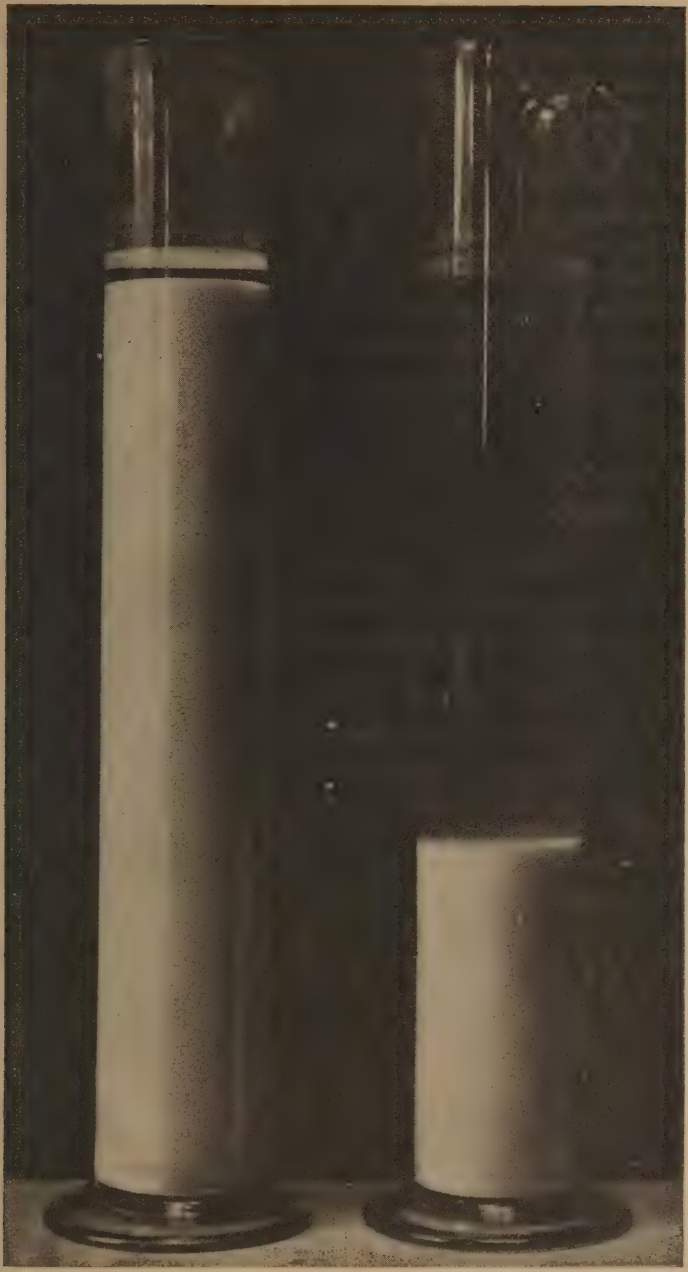


PLATE IX.

BORDEAUX MIXTURE PROPERLY AND IMPROPERLY PREPARED, AFTER SETTLING ONE HOUR.

pint is used in the neutralization, and if it is desired to have the lime of the same strength as the sulphate solution, it will require one-half pint of water for each one-half pint of lime milk; therefore, the total quantity of the latter will simply have to be doubled, by adding an equal quantity of water. If only one-quarter pint was necessary to accomplish the neutralization, the total would have to be quadrupled, or three times the quantity of water added. In large-scale operations this standardizing of the lime milk will be found very advantageous, especially where the mixing is not all done by the same man. In this case, the standardizing can be done by the foreman, or head operator, and then the spray crews have simple, straight measuring to do.

PROPER METHOD OF PREPARING BORDEAUX MIXTURE.—Nothing but fresh or quick lime should be used. Air-slaked lime is very unsatisfactory and should never be used. Slake the lime carefully and slowly by adding the water gradually—just enough to keep it moistened during the slaking process. In this way a clean, smooth paste will be formed, yielding a milk with very little grit, if the lime is of good quality. In keeping the lime paste through the season, it is essential to have it covered with water. If allowed to dry it will work up gritty, and vexatious clogging of the nozzle will follow.

The proper mixing of the two solutions is of the utmost importance. *Never mix the concentrated solutions together*, and always allow them to become thoroughly cooled before mixing. The latter precaution applies, of course, when the sulphate is dissolved in warm water, and especially to newly slaked lime, which, on the whole, is better prepared at least twenty-four hours before using.

To make Bordeaux mixture properly, dilute the copper sulphate solution and the lime milk before mixing them together; i. e., if 50 gallons of mixture are being prepared, dilute each to about 24½ gallons. This will give a one-gallon leeway and thus allow the addition of more lime in case the test indicates a shortage.

If these injunctions are not heeded, the resulting mixture will be very unsatisfactory, to say the least. If mixed concentrated and then diluted, or if mixed while warm, the precipitate will form in large flakes, which will not remain long in suspension and which cannot, therefore, be so effectively distributed. It is also probable that the compound of lime and copper thus formed may be different and less effective. Plates VIII. and IX. are reproduced photographs of cylinders of Bordeaux mixture properly and improperly made. The cylinder on the left contained the mixture properly made by diluting the stock solutions before mixing. The

mixture in the right-hand cylinder was made by mixing the concentrated stock solutions and then diluting. The pictures were taken after settling twenty minutes and one hour respectively, and show how widely different are the mixtures made by the two methods. In the first case, it will be seen that the properly made mixture had hardly begun to settle, while the other had already gone down nearly six inches. After one hour, the properly made mixture had settled only about an inch, the improperly made, about twelve inches. It will thus be seen how vastly important is the proper preparation of this valuable fungicide. A mixture with the "staying-up" qualities, shown in the left-hand cylinder, will not require constant agitation; stirring every ten minutes will be amply sufficient. A mixture like that in the right-hand cylinder could not be uniformly distributed without constant and most thorough agitation. The saving of labor is alone sufficient to warrant the extra care, aside from the possibility of producing a more active fungicide.

Mixing Outfits.—Where a large quantity of Bordeaux mixture has to be prepared, a good mixing outfit or elevated system of mixing tanks, will greatly facilitate the work. Such a system allows of easy and quick handling of the solutions and when properly arranged will simplify the mixing operations, and consequently often avoid costly and annoying mistakes. There is opportunity here for the grower to display his ingenuity in devising an outfit which will best suit his purpose. Several such outfits are at present in use in Illinois. Perhaps the first to be constructed here is that devised in 1899 by R. A. Simpson of H. M. Simpson & Sons and used by him with great success during the past two seasons in their 160-acre orchard at Parkersburg. It is the best of its kind now in use in this state. Mr. Simpson has kindly consented to give the fruit-growers of Illinois the benefit of his experience and has furnished the sketch from which the plan reproduced in Fig. 2 was made, together with the following description of the system:

"(*a*) and (*b*) represent diluting tanks of 130 gallons capacity each.

"(*c*) represents a mixing tank of 250 gallons capacity.

"(*d*) is a very fine strainer (brass cloth wire, 20 meshes to the inch) attached to the bottom of a wooden box, which is supported by four legs long enough to reach to the bottom of the mixing tank.

"(*e*) is a cylinder force-pump capable of throwing a two-inch stream.

"(*f*-*g*) is a piece of 2-inch hose to which a pipe (*g*) to (*b*) with a goose-neck is attached.

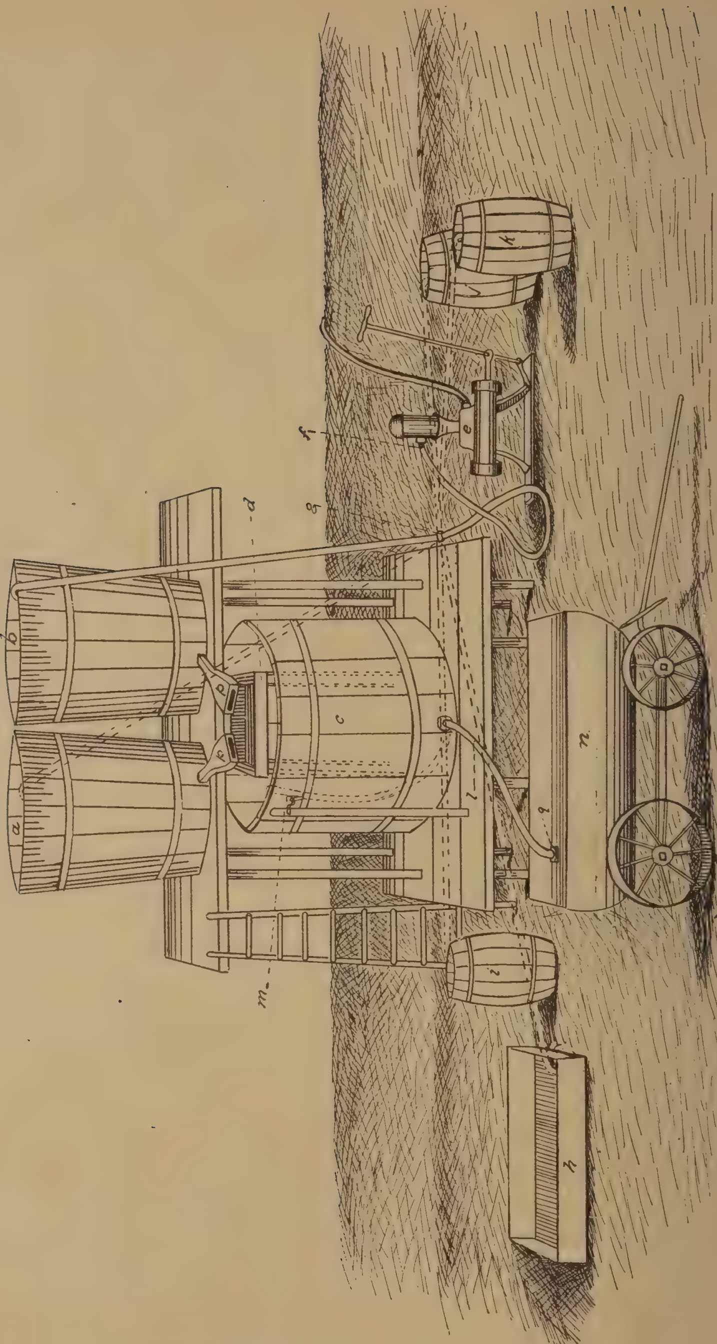


FIG. 2.

"(*h*) is a box for slaking lime.

"(*i*) is a barrel of milk of lime made up from the lime paste prepared in *h*, first run through a coarse sieve.

"(*j*) and (*k*) are barrels filled with copper sulphate stock solution.

"(*l*) is a piece of 2½-inch hose, through which the mixture from (*c*) runs to spray tank (*n*.)

"(*m*) is a stake with a hook or other contrivance at its upper end to hold the end of the hose (*l*) above the level of the liquid in the mixing tank.

"(*pp*) are spouts specially devised for throwing the liquids in wide, flat streams.

"The pipe (*g*) to (*b*) can be moved by a man standing on the ground, to either (*a*), (*b*), (*h*), (*i*), (*j*), (*k*), or any place within reach; thus allowing easy distribution of water to any point in the system. We get our water supply from ponds.

"The mixing tank (*c*) must be so placed that the bottom will be a little higher than the top of the spray tank (*n*) when the latter is driven up to be filled. The bottoms of the tanks (*a*) and (*b*) must also be higher than the top of (*c*). It is also advantageous to have the bottoms of the tanks sloping forward, to allow of draining out the liquids.

"When the system is put into operation, the hose (*l*) is hooked to the stake (*m*). If 4-4 strength of Bordeaux is being used and the spray tanks hold 200 gallons, lime milk containing 16 pounds of lime is taken from (*i*) and put into the diluting tank (*a*). Likewise, 16 gallons of the stock solution, containing 16 pounds of copper sulphate, in (*j*) and (*k*) are put into diluting tank (*b*). Then 100 gallons of water are pumped up into each of the diluting tanks. Then the diluted solutions are thoroughly stirred before turning on the faucets (*pp*). The latter are so placed that the thin, broad streams will come together and mix as they fall through the strainer (*d*) into the mixing tank (*c*). The mixture in (*c*) is then stirred, tested, and rectified, if necessary. As soon as this is done, the driver of the spray tank lowers the hose (*l*), thus allowing the mixture to flow into the tank at (*q*) where another strainer is placed.

"If there should happen to be no empty spray tank in at the time the mixture is made up, the diluting tanks (*a*) and (*b*) are again charged as before, ready for another full tank of mixture. Then while the empty spray wagon is being filled, the faucets (*pp*) can be turned on without waiting for the mixing tank to become empty. Thus two spray tanks can be filled without delay. We find that in this way one of our 200-gallon tanks can be filled

in three minutes, and as soon as one wagon pulls out there is a full tank of mixture ready for the second.

"Two men do all the mixing and test each tank with the ferrocyanide test for four 200-gallon outfits. Last year we averaged 5½ tanks per day for each outfit, and in one instance 7½ tankfuls were made and applied by one outfit in a day's run. We find the mixture prepared in this way very uniform and satisfactory, and we are fully satisfied with the expenditure."

Mr. Simpson makes no mention of the cost of constructing such a system. It is probable, however, that it will involve considerable expense. If properly built and cared for, it will last a long time, and will no doubt prove a paying investment.

The outline of this system is given as a suggestion to growers with large areas under cultivation. No doubt it may have to be improved or modified to suit the conditions at different places. Thus, for example, it may prove an advantage in some instances to construct a third and higher platform, upon which the lime paste, lime milk and copper sulphate stock solutions can be prepared. In this way the unbroken barrels of lime and sulphate can be hoisted up to the platform instead of being carried up piece-meal, as they are in the system described. Whether these added improvements would pay or not, must, of course, be decided by each grower for himself.

IMPORTANT MINOR DETAILS.—The lime milk should be carefully strained, for despite the most careful slaking there will always be a quantity of gritty particles. There can be no doubt that straining is rather a tedious operation, but the writer has always found it to pay in the end, saving many vexatious and discouraging delays. It takes only a comparatively few gritty particles to worry one for hours, and even days. If the strainer is made large enough, it will not be found to clog as do the small ones in general use. The writer saw one operator who uses hundreds of gallons of Bordeaux, straining his lime milk through an ordinary milk strainer! That, of course, is time wasted. Where the lime milk is poured into an open barrel for dilution (as it should be for proper mixing) a 20-mesh brass wire strainer made to fit over the entire area of the barrel head will be found to work very satisfactorily. Such a strainer will, of course, have to be made to order, but it will pay in the end.

Whenever the tanks or apparatus are to stand unused for a time they should be thoroughly cleaned. Merely filling the tanks with water will not do. All clinging particles of the mixture should be removed by running through a few gallons of cheap, vin-

egar or dilute acetic acid. If the accumulated mixture is allowed to remain in the tanks or to dry in the spraying apparatus, scaly particles will form, and cause most annoying clogging of the nozzles the next time the outfit is used.

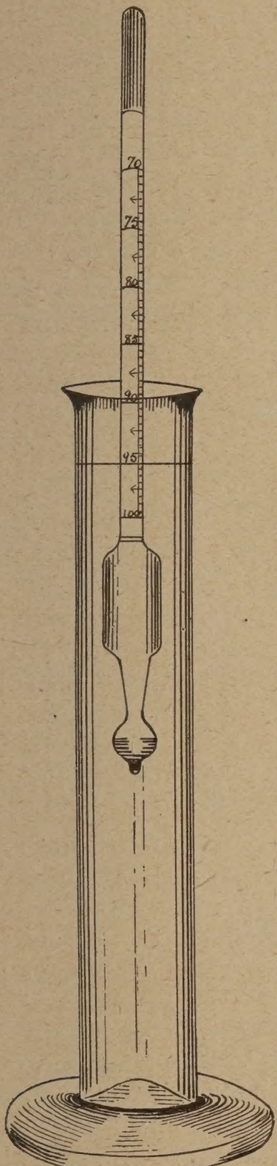


FIG. 3.

These small details may seem unimportant and tedious to many. They are, however, some of the little things, which, when neglected, may often prove the main causes of failure.

AMMONIACAL COPPER CARBONATE.—This solution consists of the commercial copper carbonate dissolved in diluted ammonia water. The proportions as recommended at present are :

Copper carbonate............	5 ounces.
Ammonia (26° Beaume)......	3 pints.
Water....	50 gallons.

This is a very valuable fungicide, especially for late use when the discoloration of the Bordeaux mixture is objectionable. The solution is clear and of a light blue color and when dried upon the foliage or fruit leaves practically no stain. It is said to be not quite so effective a fungicide as the Bordeaux mixture—perhaps on account of the smaller amount of copper present in the strength of solution recommended. As compared with Bordeaux, the solution contains about one-tenth the quantity of copper, which is the active principle of the fungicide.

Copper carbonate as commercially manufactured is pure enough for all practical purposes. The 26-degree ammonia water is more liable to variation. The nature of its composition is such that the solution (it is simply a solution of ammonia gas in water) is liable to become weakened by evaporation. The commercial ammonia water when up to full strength (26° Beaumé) contains about 25% of ammonia, and it is upon that strength that the quantity required for dissolving the copper carbonate is based. All of the copper salt must be dissolved ; therefore, if the ammonia water is weak, a larger quantity must be used, but no more than

just enough to dissolve the carbonate. It is advisable for those who contemplate using this solution to any extent to provide themselves with a "specific gravity spindle" (Fig. 3) for testing the strength of ammonia in the ammonia water they intend to use. Fill a tall cylinder (such as shown in Fig. 3) with ammonia water, and allow the spindle to float in it. The depth to which the bulb will sink depends upon the density of the liquid. The stem of the instrument is graduated and the figure just at the surface indicates the specific gravity or relative density as compared with pure water. This specific gravity in turn indicates the percentage of ammonia gas in the solution, which can be found by reference to the appended table. With this test the grower is enabled to know exactly what strength of solution he has to deal with. Thus, dangerous guess work is avoided—an important factor in the use of ammonia upon living plants.

*TABLE SHOWING PERCENTAGES OF AMMONIA IN SOLUTIONS OF THE GAS IN WATER, AS INDICATED BY THEIR SPECIFIC GRAVITIES.

Specific gravity.	Per cent of ammonia.	Specific gravity.	Per cent of ammonia.	Specific gravity.	Per cent of ammonia.
.960	9.51	.932	16.81	.904	24.39
.958	10.03	.930	17.34	.902	24.94
.956	10.54	.928	17.86	.900	25.50
.954	11.07	.926	18.42	.898	26.05
.952	11.59	.924	18.93	.896	26.60
.950	12.10	.922	19.67	.894	27.15
.948	12.62	.920	20.01	.892	27.70
.946	13.13	.918	20.56	.890	28.26
.944	13.65	.916	21.09	.888	28.86
.942	14.17	.914	21.63	.886	29.46
.940	14.69	.912	22.19	.884	30.14
.938	15.21	.910	22.74	.882	30.83
.936	15.74	.908	23.29		
.934	16.27	.906	23.83		

**Beaume 16° indicates .960 sp. gr.
Beaume 20° indicates .936 sp. gr.
Beaume 22° indicates .924 sp. gr.
Beaume 24° indicates .913 sp. gr.
Beaume 26° indicates .901 sp. gr.

METHOD OF PREPARING THE COPPER CARBONATE SOLUTION.—The ammonia should be diluted before using to dissolve the carbonate. The writer has found the following method the most satisfactory for getting all of the copper salt into solution: First wet the carbonate thoroughly by making a thin paste of it with water.

*Compiled from the Table of Lunge und Wernik, cited by Caldwell: "Elements of Chemical Analysis," page 173.

**Lodeman: "The Spraying of Plants," page 116.

Upon this paste pour one-third of the ammonia, say one pint to five ounces of carbonate, diluted seven or eight times. Stir vigorously several times and allow to stand until the undissolved salt has entirely settled. Pour off the clear liquid. Upon the remaining salt pour a second pint of ammonia diluted five or six times. Stir again and allow to settle as before. Pour off the clear liquid adding it to the first portion. On the remaining sediment pour a third pint of ammonia diluted two or three times (if weaker ammonia is used, no dilution will be necessary). This last pint should dissolve all the remaining sediment. If the ammonia has been found weak, add more ammonia until all the remaining copper salt enters into solution. Pour all of the solution together and dilute to the required spraying strength. If other than rain water is used in diluting the ammonia, a cloudy, flocculent precipitate may be formed, which should not be mistaken for undissolved copper carbonate. The latter is a light, bluish-green, flaky substance and can be easily distinguished from the darker, cloudy, larger floccules of the precipitate from the water. Wherever possible it is best to use rain water in diluting the ammonia for dissolving the salt. The floccules do no harm. The danger lies in mistaking them for undissolved carbonate and adding enough ammonia to dissolve them.

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